Regional Beach Sand Retention Strategy

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REGIONAL BEACH SAND RETENTION STRATEGY

FINAL REPORT

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1.0 INTRODUCTION

1.1 BACKGROUND

SANDAG adopted the Regional Shoreline Preservation Strategy in 1993. Sand retention strategies are recognized in the Shoreline Preservation Strategy as one of a number of tactics that can be used to complement the placement of sand on the region's beaches. Sand retention has the potential to increase the cost effectiveness of beach replenishment activities, and may even help to reduce potential environmental effects of beach filling by protecting sensitive resources such as reefs and lagoons from sedimentation, and possibly providing new habitat areas.

1.2 APPROACH

In order to assess and take advantage of the potential benefits of sand retention, SANDAG has approved the preparation of a Sand Retention Strategy that includes the following components:

- Evaluation of retention strategies at the most appropriate locations along the region's shoreline, and within every local coastal jurisdiction..

- Evaluation of natural features, such as points, bays and pockets along the coast, as well as soft and hard structures, as potential features to retain sand.

- Use of the policies in the Shoreline Preservation Strategy to guide the evaluation, including evaluation of costs, benefits of reduced need for beach filling, possible negative affects on down-coast beaches (sand losses), and methods to compensate for any sand losses.

- Preliminary assessment of environmental affects of strategies and projects on lagoons, reefs and kelp beds.

- Development of preliminary designs and cost estimates for sand retention strategies that are consistent with Shoreline Preservation Strategy policies and have minimal or mitigable environmental impacts and consideration of possible downcoast erosion impacts.

- Continuing consultation with the coastal jurisdictions and the Shoreline Preservation Committee in carrying out the work, including input from coastal jurisdictions and review by the Shoreline Preservation Committee.

It should be noted that this study represents the first step in what must be a carefully planned process that may ultimately result in regional beaches enhanced by retention structures. Findings in this report are based on reconnaissance-level evaluations.

1.3 SCOPE OF WORK

The scope of work for development of the sand retention strategy included the following tasks:

Task 1 – Review Existing Studies and Data

The focus of this task was to define the starting point for development of the Regional Beach Sand Retention Strategy. The purpose was to summarize site conditions and retention structure performance, augmented by available studies and data gathered by others. Key topics were to include:

- Littoral Processes and Sediment Budgets
- Efficacy of Natural and Artificial Sand Retention Measures
- Environmental Resources

A detailed bibliography of reviewed documents is provided in Section 6.0.

Task 2 – Evaluate Retention Strategies at Appropriate Locations

This task consisted of a methodical assessment of (1) needs, (2) constraints; and (3) opportunities for sand retention strategies by location. Retention measures were considered on a region-wide basis to maximize regional benefits, and complement future possible replenishment activities. At minimum, one measure was considered within each City.

Needs Assessment

In general, the sand retention strategy is focused on areas of greatest need for beach replenishment. Beach sand provides benefit both in terms of increased recreational opportunities and enhanced shore protection. Recreational needs were assessed by considering potential for enhanced public usage associated with a widened beach, based on historic records of beach attendance and location relative to parking facilities and access routes.

Shore protection needs were also considered for both public and private property using the DBAW (California Department of Boating and Waterways) study of 1995 and recent applications for shore protection in the region's coastal cities (including the local comprehensive beach and bluff plans). While the need for protection of public property is clearly in the public interest, widening of beaches fronting private property also provides a direct public benefit by reducing the need for seawalls and other hard shore-protective devices, and improving lateral public access.

Constraints Assessment

Given the establishment of needs by location, the next step in this task was to assess important constraints that may limit the location, extent and type of retention measure strategies considered for application. Existing detailed maps of sensitive environmental resources that may pose constraints either to retention structure placement or potential for increased sand coverage and/or lagoon in-filling associated with structure implementation were closely reviewed. Secondly, the potential for downcoast impacts associated with retention measure implementation was critically assessed, along with acceptable mitigation measures. Thirdly, certain aesthetic or recreational constraints were considered that may also limit and/or possibly eliminate certain measures otherwise considered effective candidates.

Opportunities Assessment

The focus of the opportunities assessment was to analyze both existing natural and man-made features that function as effective sand-blocking structures and assess both their performance as well as potential impacts. Opportunities to further enhance the beneficial sand blocking effect while not producing unacceptable downcoast impacts were assessed in the same fashion.

Opportunities were evaluated for application of retention measures in areas where need has been established and yet insufficient opportunity to augment existing natural or man-made features exists. This resulted in recommendations for new, man-made measures at these locations. Man-made measures range from traditional features (groins and offshore breakwaters) to less-traditional features (naturalized headlands or reefs) and were considered based on site-specific needs and community characteristics.

Opportunities to use man-made measures to protect or enhance nearshore reef habitat and lagoons were considered in their evaluation.

Strong emphasis was placed on opportunities to utilize innovative construction materials and methods to improve the aesthetic quality of any proposed sand retention measures by giving them a naturalized appearance.

Task 3 – Perform Screening-Level Analysis Of Sand Retention Concepts

The potential to increase the cost effectiveness of beach replenishment through sand retention was assessed on a site by site basis. The assessment of efficacy included both the initial re-distribution of existing and with project beach fills, as well as the expected frequency and amount of future fills to provide an agreed upon minimum beach width. Associated first construction and future maintenance costs were estimated for the purposes of alternative ranking. For new features, the analysis generally included the steps of:

- Determining the beach area created by the feature at future equilibrium;
- Converting the area into the sand quantity;
- Calculating the cost to install the feature (if applicable) and pre-fill it with sand to create the equilibrium form (assuming that no downcoast effects will result or that they are fully mitigable);
- Defining the most appropriate downcoast beach mitigation measure and calculating any mitigation costs;

- Calculating the cost to nourish the beach without the feature to create the equilibrium form;
- Assessing the potential environmental impacts and/or benefits of the feature, possible environmental issues to be considered in design, and possible environmental mitigation costs; and
- Assessing the performance and cost-effectiveness of the feature by comparing these costs.

2.0 EVALUATION OF RETENTION STRATEGIES AT APPROPRIATE LOCATIONS

The general approach of this assessment was to contact individual cities to determine what they felt the key needs and constraints were such that opportunities for sand retention could be focused appropriately. City representatives also provided input regarding types of retention strategies they felt were appropriate for their respective cities, though generally taking care to qualify that their recommendations were based on their opinions of what they felt would be desired and acceptable, and not necessarily advocating such strategies.

A brief glossary of coastal engineering terms used in this report is included in Section 5.0 of this report.

2.1 NEEDS ASSESSMENT

Each of the coastal communities focused primarily on recreational beach area, property protection behind the beach, and the preservation or enhancement of surf breaks as their most noteworthy concerns. The first two focus on the character of the beach and the third on the character of the nearby seabed. Needs were stated in meetings with City staff and are summarized below.

<u>Oceanside</u>

Oceanside identified the need to reduce future coastal armoring by increasing the beach width. City staff requested that a groin or group of groins be evaluated at Buccaneer Beach or alternatively a single groin be evaluated adjacent to the pier. Any structures to be constructed were specified to be exposed above the water surface to be visible and not present a submerged navigation or safety hazard. If possible, they should be naturalized in appearance. A chief concern was to not cause downcoast impacts to the region. Any local or regional project should be coordinated with a potential federal project to mitigate Harbor impacts.

<u>Carlsbad</u>

Carlsbad requested the evaluation of a submerged reef, with a possible emergent component located offshore the beach between Pacific Avenue and Oak Avenue. Encinas Creek Beach, just south of Terra Mar Point, was selected as an alternative site. Staff noted they would prefer a feature along their more intensively-used downtown coastal area. The structure should have effects that are not detrimental to Agua Hedionda or Buena Vista Lagoons. The proposal to extend the north jetty at Agua Hedionda Lagoon was to be referenced but was not identified to be the retention measure assessed as a part of this study. The fillet beach to be created was preferred to be long and narrow rather than short and wide.

Encinitas

Encinitas identified three objectives to meet for a sand retention measure. One is to promote sand accretion; a second is to allow sand to pass by the feature while retention occurs and the third is to preserve and enhance (if possible) surfing as a resource. A submerged structure was preferred, but an emergent component may also be appropriate if required for sand retention performance. It must look natural if it is emergent. The sand deposit must not block longshore sediment transport. Moonlight Beach is the primary site for the structure, and Leucadia is a secondary site. Creation of habitat should also be a goal with any structural feature.

Solana Beach

Solana Beach desires increased recreational beach area and a pilot project that could be applied to increase property protection in the future. The City staff indicated a submerged reef at Fletcher Cove would be preferred for sand retention. An emergent component would also be considered if necessary. A submerged reef should be designed to not adversely affect surfing, but rather to improve it. An emergent reef should appear naturalized.

Del Mar

Del Mar possesses the attribute of an accretional beach at the north portion of the coast and may not need a beach retention structure in their jurisdiction. Rather, a retention strategy could be to place future sand north of Powerhouse Park to maximize its retention within the City. Creation of new habitat should be a criterion for the project

San Diego

The City of San Diego is concerned about protecting Highway 101 along Torrey Pines State Beach. A submerged reef at the south end of the Penasquitos Lagoon was suggested for consideration to widen the beach and protect the highway. Improved surfing would also be a desirable benefit provided by the reef. Adverse impacts should not occur at the State beach south and Del Mar to the north.

Coronado

Coronado needs a strategy that will retain sand, provide a recreational benefit, is safe for the public and does not adversely effect the beach at the Hotel Del Coronado. The site for the strategy is the 3,000-foot long reach south of the groin structure at the Hotel Del Coronado. It borders the Coronado Shores condominium complex and is north of the US Navy Amphibious Base. Options include a submerged reef that provides a surfing benefit, or a groin similar to that at the Hotel Del Coronado, or a new stub groin off of the existing groin. A relic shipwreck exists off of the Shores condominiums and presents a public safety hazard. The City needs to cap it with material to eliminate protrusions through the sand at low tide. A project over the site could add the benefit of covering the ship.

Imperial Beach

Imperial Beach needs a wider beach along the southern 3,000-foot long reach at Seacoast Drive, between the south end of the street and Imperial Beach Pier. They desire less hard shore protection along this coast by widening the beach. A submerged reef that provides a surfing benefit was identified as a preferred measure, or expanding the Tijuana River delta to advance the entire coast seaward. Impacts to the Tijuana River Estuary and dunes complex are to be completely avoided.

Summary

The needs as described by each local city is summarized in Table 2-1.

Table 2-1 Results of Interviews for SANDAG- Retention Measure Strategies in Each City

City	Location	Retention Measure(s)	Considerations/Comments
Oceanside	Buccaneer Beach	Groin Compartment	Place sand dredged from harbor on beach downcoast from groins; design to avoid downcoast impacts; consider integration with Federal project; Alternative could be groin under pier.
Carlsbad	North beach area, between pacific Ave., and Oak Ave.	Reef – submerged or a mix with an emergent component	Do not analyze Agua Hedionda Lagoon Jetty extension, but refer to previous SANDAG work done on it, caveated as not being as detailed as current effort; project would benefit recreation and tourist area. Surfing benefit would be a plus.
Encinitas	Moonlight Beach; Alternate site is Leucadia (between Beacons and Moonlight)	Reef – submerged (if possible); would consider emergent reef if necessary	Make larger than Pratte's Reef in El Segundo and use rock. If emergent, reef must look naturalized; reef must retain sand and allow sand to pass between reef and the beach; reef must provide a surfing resource and biological habitat.
Solana Beach	Fletcher Cove	Reef – either submerged or emergent	Compare performance of submergent versus emergent. If submergent, design as surf reef for acceptance. If emergent, make look natural where exposed. Estimate cost difference surfing versus non-surfing reef. Design for habitat creation.
Del Mar	Between Powerhouse Park and the northern City boundary	Natural acccretional	Area naturally retains sand, and it should be considered as the placement area for any future replenishment efforts.
San Diego	Torrey Pines with Mission Beach as an alternate site	Reef –either submerged or emergent	Prefer submerged; would protect Highway 101 at Torrey Pines. Avoid lagoon (North) and surfgrass (South). Property is State-owned. Must provide surfing and offshore habitat benefits. Alternative would be a groin under Crystal Pier.

Table 2-1 Results of Interviews for SANDAG- Retention Measure Strategies in Each City (Continued)

City	Location	Retention Measure(s)	Considerations/Comments
Coronado	The Shores Condominium south of the Hotel Del Coronado	Extend existing hotel groin perpendicular to beach or install new groin to south to mimic existing groin; alternative could be submerged/emergent reef	Measure must not pose a safety hazard or affect downcoast, particularly at the Hotel's beach. A narrow beach exists south of existing groin from development on sand and portions of a sunken shipwreck are exposed at low tide. Want to encase portions of ship in concrete that may be opportunity for reef construction. Consider dredging from Zuniga shoal as done by NAVY, and improve sand trapping function of jetty by "sealing" it and installing dog-leg on end to south. Consider NAVY and State for funding.
Imperial Beach	South end of Seaccoast Drive		Should have surfing component; avoid kelp beds as constraints.

2.2 CONSTRAINTS ASSESSMENT

Constraints to sand retention exist along the region’s coast. They consist of sensitive environmental resources and existing surfing locations. The map attached with this report identifies constraints in a qualitative fashion, with coastal areas designated with a green color bar as not constrained, a yellow bar as moderately constrained and a red bar as highly constrained. North County beaches are the most constrained, with South County being less constrained. All sites could realize benefits from placement of reef habitat. Either reef would be created where it does not exist or existing higher quality reefs would be expanded. Particularly good candidate sites are identified below in the discussion for each city.

Oceanside

The Oceanside shoreline exhibits only moderate constraints consisting of nearshore scattered rocks at the southern beaches. Buccanneer Beach is not constrained.

Carlsbad

Carlsbad is more constrained, with sensitivity near two lagoon mouths, nearshore reef, surfgrass areas, kelp beds and surfing sites. Constraints are mostly moderate, with only two locations of high constraints at Agua Hedionda Lagoon and Terra Mar Point. North Carlsbad is moderately to highly constrained. The north end of South Carlsbad State Beach is less constrained and is a good candidate for expansion of higher quality nearshore reef. A biological benefit may be realized from placing an artificial reef at this location. More biological reconnaissance work may be needed to define potential impacts at this site.

Encinitas

Encinitas is similarly constrained with nearshore reef areas, surfgrass areas, historic kelp beds and surfing sites. Two sites are highly constrained at Swami's Park and Cardiff Reef and the rest are moderately constrained. Moonlight Beach is less constrained, and is also a good candidate for expansion of higher quality nearshore reef than presently exists. A biological benefit may be realized from placing an artificial reef at this location as well. Leucadia is moderately constrained.

Solana Beach

Solana Beach is moderately constrained throughout to highly constrained at Seaside and Tabletop Reefs. Fletcher Cove at the south end is less constrained, and is also a good candidate for expansion of higher quality nearshore reef than presently exists. A biological benefit may be realized from placing an artificial reef at this location as well. More biological reconnaissance work may be needed to define potential impacts at this site.

Del Mar

Del Mar is either not constrained or only moderately constrained throughout the City. A moderate constraint exists at the mouth of San Dieguito Lagoon and no other constraints exist north of Powerhouse Park. South of Powerhouse Park the City is moderately constrained by reefs.

San Diego

San Diego ranges from no constraints, to moderate and then to highly constrained. Torrey Pines Beach is not constrained immediately south of Los Penasquitos Lagoon, then moderately constrained at the south end.

Coronado

Coronado Beach is not constrained.

Imperial Beach

Imperial Beach is only constrained at the very south end toward the Tijuana River. The south end of Seacoast Drive is moderately constrained with kelp offshore.

Summary

Sites that are either not constrained or only moderately constrained for sand retention at each City are summarized in Table 2-2.

Table 2-2 Sites With Moderate to No Environmental Constraints

City	Locations with Moderate to No Environmental Constraints
Oceanside	Buccaneer Beach
Carlsbad	South Carlsbad State Beach at the north end
Encinitas	Moonlight Beach
Solana Beach	Fletcher Cove (south end)
Del Mar	North of Powerhouse Park
San Diego	Torrey Pines just south of the Los Penasquitos Lagoon inlet
Coronado	Off of the Shores condominiums
Imperial Beach	South end of Seacoast Drive

2.3 OPPORTUNITIES ASSESSMENT

Coastal engineering design is greatly aided by prior experience with similar structures in similar environments. A critical aspect in the development of the retention strategy, therefore, was the assessment of existing natural and artificial features that function as effective sand blocking structures. Unfortunately, there is a general deficiency of both natural and artificial structures in the San Diego region that retain substantial beaches, particularly within the Oceanside Littoral Cell from Oceanside Harbor to Point La Jolla.

A key first step in the assessment of sand retention opportunities was to summarize our understanding of sand transport within the region. Accurate net and gross longshore sand transport rates are required to predict the functional behavior of structures and to forecast their impacts on downcoast beaches. A summary of the longshore sand transport characteristics within the region is provided in Appendix 2.

Given our understanding of sand transport within the region, the next step was to assess the performance of existing sand retention structures in the region. The assessment included both natural features and artificial structures. Results of this opportunities assessment are summarized in Table 2-3 and Table 2-4. Please refer to Appendix 3 for more detailed analysis and discussion.

Table 2-3 Assessment of Sand Retention Opportunities in Oceanside Littoral Cell

Structure(s)	Natural or Artificial	Comments	Reference Figure
• Headland North of Ponto Beach (Carlsbad) • Swami's Headland (Encinitas) • Reef off San Elijo Lagoon (Encinitas) • Reef at North Solana Beach	Natural	• These natural features retain very little dry beach width for their size • Offer limited clues that could be used in design of artificial measures	
• Point La Jolla	Natural	• Effective sand retention feature • Prevents sand passing to south • Retains beach at La Jolla Shores • Effectiveness relative to impact of La Jolla Canyon unclear	
• North Breakwater at Oceanside Harbor	Artificial	• Present configuration constructed in 1963 • Retains beach up to 4,500 feet to the north • Retained beach area from 600,000 to 750,000 square feet • Acts like a groin • Fillet angle of 6 degrees • Blocking distance of 500 feet • Significant downcoast impacts	Figure 2-1
• South Breakwater at Oceanside Harbor	Artificial	• Complex orientation (two segments with outer segment oriented to the southeast) does not allow for useful assessment of performance factors	Figure 2-1
• Groin at Mouth of San Luis Rey River (Oceanside)	Artificial	• Constructed in 1968 • Performance affected by proximity to Oceanside Harbor • Blocking distance on upcoast (north) side of 500 feet • Blocking distance on downcoast (south) side of 650 feet • Fillet angle in offshore direction due to shadowing effect of harbor	
• Temporary Groin at Buccaneer Beach (Oceanside)	Artificial	• Constructed in early 1970s as temporary structure to assist in construction of outfall through surf zone • Photo gives no indication of sand fillet • Blocking distance on upcoast side of 800 to 1,000 feet • Blocking distance on downcoast side of 700 to 900 feet • Insufficient time for shoreline to reach dynamic equilibrium, so blocking distances not representative of long term performance	Figure 2-2

Table 2-3 Assessment of Sand Retention Opportunities in Oceanside Littoral Cell (Continued)

Structure(s)	Natural or Artificial	Comments	Reference Figure
• North and South Jetties at Agua Hedionda Lagoon (Carlsbad)	Artificial	• Constructed in 1954 • Purpose was to control entrance location and keep it open to allow continuous supply of cooling water • Act as groins • Apparent blocking distance on north and south jetties is 150 feet and 250 feet, respectively • Performance assessment complicated by proximity of hardened shoreline and function within a lagoon barrier shoreline • Fillet angle of approximately 2.5 degrees • May be functioning more to prevent shoreline from curving inward at the lagoon outlet than retaining sand as sediment blocking structures	
• North and South Jetties at Agua Hedionda Lagoon at Power Plant Outfall (Carlsbad)	Artificial	• Constructed in mid-1950s • Similar assessment as jetties to the north	
• North and South Jetties at Batiquitos Lagoon (Carlsbad)	Artificial	• Excluded from assessment since have not been in place for sufficient time to attain dynamic equilibrium.	

Figure 2-1 North Breakwater at Oceanside Harbor and the Upcoast Retained Beach (February 1975)

Figure 2-2 Aerial Photograph of a Temporary Groin at Buccaneer Beach (1971)

In contrast to the Oceanside Littoral Cell, natural retention structures are primarily responsible for the configuration of the Silver Strand Littoral Cell, which stretches from the Zuniga Jetty at the entrance to San Diego Bay to a rocky headland at the south end of the Playas de Tijuana. The primary natural retention structures include the Point Loma headland at the north end of the cell, and the Tijuana River delta to the south.

In addition to natural retention structures in the Silver Strand Cell, four permanent and one temporary artificial structure either retain beach presently, retained beaches in the past, or were designed to retain beaches without success. The performance of both natural and artificial retention structures is summarized below in Table 2-4.

Table 2-4 Assessment of Sand Retention Opportunities in Silver Strand Littoral Cell

Structure(s)	Natural or Artificial	Comments	Reference Figure
• Point Loma headland	Natural	• Blocks and diffracts waves that approach from the north and northwest • Reduces the amount of unobstructed deep water wave energy that reaches the north half of the cell in its lee	
• Tijuana River delta / Delta Point	Natural	• Natural wave refraction and dissipation structure • Retains Delta Point which in turn holds the beach position at this location (both to north and south)	
• Zuniga Jetty (Point Loma)	Artificial	• Constructed in 1893-1904 • Largest of artificial sediment blocking structures in the Silver Strand Cell • Prevents sand from moving from south into entrance to San Diego Bay • Holds beach up to 1,250 feet wider than pre-jetty (and pre-beachfill) shoreline • Any modification to this structure would be of little net benefit to public beaches	
• Hotel del Coronado groin (Coronado)	Artificial	• Constructed in 1897-1900 • Original purpose to provide calm water for launching and mooring of small craft • Functions as sediment blocking structure (groin) and wave blocking/diffraction structure (breakwater) • Intriguing feature in that it retains sand on its downcoast (north) side • Historically retained 350,000 square feet of beach prior to major beachfills • Prior to major beachfills, had shore-normal blocking distance of 700 feet (comparable to Imperial Beach), with fillet angle of 2-3 degrees • Presently retains less than one acre of beach	Figure 2-3 Figure 2-4
• Historic shipwreck (Coronado)	Artificial	• Observed in 1938 photograph • Created salient of 50,000 square feet • Provides useful information regarding efficacy of small offshore breakwater	Figure 2-4

Table 2-4 Assessment of Sand Retention Opportunities in Silver Strand Littoral Cell (Continued)

Structure(s)	Natural or Artificial	Comments	Reference Figure
• Imperial Beach Groins	Artificial	• Constructed between 1959 and 1963 • Ineffective at retaining a wider beach • Evidence indicates groins are too short to be effective • North groin length of 740 feet only slightly exceeds required blocking distance of 700 feet for a high, impermeable groin at Imperial Beach • Would need to lengthen North groin a few hundred feet to retain a year-round fillet on the upcoast (south) side. • South groin is only 400 feet long, requiring greater additional length than the north groin to act as an effective sand blocking structure	Figure 2-5

Figure 2-3 Sediment Blocking Structure at the Hotel del Coronado

Figure 2-4 Salient in Lee of Shipwreck off Coronado (1938 Photo)

Figure 2-5 Groins at Imperial Beach

2.4 RETENTION STRATEGIES BY LOCATION

The thrust of this overall task was to conduct a methodical assessment of needs, constraints and opportunities for sand retention strategies by location. A minimum of one measure was specified to be considered for each city. Table 2-5 summarizes the sand retention strategies considered for each city, based upon input from each city as well as the results of the needs/constraints/opportunities assessment described in this report section.

Table 2-5 – Sand Retention Strategies by Location

City	Retention Strategy	Discussion
Oceanside	• Groin Compartment at Buccaneer Beach • City desires visible (emergent) structures only due to public safety issues	• Opportunities assessment determined groins not effective unless very long • Long groins pose major concern for downcoast impacts • The City of Oceanside requested that groins still comprise their desired strategy, with possible modifications to the existing Federal sand bypassing at Oceanside Harbor to help offset downcoast impacts • Downcoast impacts cannot be quantified at this level of study, but must be considered if groins remain the desired sand retention strategy within Oceanside • Buccaneer Beach is in need of retention and is not constrained, and therefore the appropriate site in this City
Carlsbad	• Reef in north beach area • Reef can be submerged or include emergent component	• See Section 3 for analysis of reef • Prior study (Moffatt & Nichol Engineers, 1999) included cursory assessment of extending the North Jetty at Agua Hedionda Lagoon, indicating potential economic feasibility • The present study included a more detailed look at the function of the Agua Hedionda jetties, and casts some doubt on their function as sand retention structures (see Appendix 3) • The efficacy of extending the north jetty is currently under investigation by others • North Carlsbad too constrained; South Carlsbad State Beach north end is in need and only moderately constrained, and is therefore suitable for the measure
Encinitas	• Reef in Moonlight Beach • Reef should be submerged or include emergent component if necessary	• See Section 3 for analysis • Needs are at Moonlight Beach and it is only moderately constrained, and therefore the suitable site for the measure • Moonlight Beach is suitable for habitat improvement
Solana Beach	• Reef in Fletcher Cove • Reef can be submerged or include emergent component if made to look like natural feature	• See Section 3 for analysis • Fletcher Cove is highly in need of sand and only moderately constrained and therefore the suitable site for the measure • Fletcher Cove is suitable for habitat improvement
Del Mar	• Rely on natural sand accretion area between Powerhouse Park and northern city boundary	• This coast naturally retains sand north of Powerhouse Park and does not need augmented retention. Future beach fills should be placed here while avoiding impacts to the San Dieguito River mouth.

Table 2-5 – Sand Retention Strategies by Location (Continued)

City	Retention Strategy	Discussion
San Diego	• Reef at Torrey Pines • Reef can be submerged or include emergent component	• See Section 3 for analysis • Torrey Pines State Beach just south of the lagoon is in need of sand retention and unconstrained, and therefore suitable for a measure • Retention would protect Highway 101
Coronado	• Extend existing Hotel del Coronado groin or construct new groin to south	• Opportunities assessment determined groins not effective unless very long • Could retain a significantly wider beach if long enough • Groin must be at least 800 feet long to maintain an all-season fillet • Long groin would pose major concern for downcoast impacts • Groins not recommended as sand retention strategy • In lieu of groins, Coronado could consider an offshore breakwater or emergent reef (Section 3) • The beach is in need of sand retention off of the Shores condominiums and is unconstrained, and therefore the suitable site for the measure
Imperial Beach	• Submerged reef at south end of Seacoast Drive • Should include surfing enhancement	• Health of the beach at Imperial Beach dependent on preservation of the Tijuana River delta as a beach retention structure • Delta Point is retained by the delta and, in turn, is responsible for the shoreline position to the north and south of it • Retention strategy would need to avoid kelp beds while meeting City's request for a submerged structure with a surfing component • Options include (1) artificially raising the crest of the delta to improve its function as a wave refraction and attenuation structure and (2) construct an artificial submerged reef closer to shore, possibly connected to shore • See Section 3 for analysis • The beach is in need of sand retention at the south end of Seacoast Drive and is unconstrained, and therefore the suitable site for the measure

Section 3 of this report describes a screening level analysis of the cost effectiveness of the proposed retention strategies.

3.0 SCREENING LEVEL ANALYSIS OF SAND RETENTION CONCEPTS

The purpose of this screening level analysis of sand retention concepts was to attempt to determine the cost effectiveness of the various concepts relative to beach nourishment alone without retention measures. The procedure used for the analysis is described in Section 1.3

The first and foremost step in this analysis was establishing relationships between retention measure characteristics and retained beaches. Measures identified in the preceding section that were recommended for sand retention strategies within each city include both submerged and emergent reefs; groins are analyzed as the retention strategy of choice for Oceanside, though concerns remain for potentially significant downcoast impacts.

For purposes of this study, reefs are defined as either submerged or emergent (above water) structures that allow buildup of sand on a beach due to the creation of a wave shadow zone on the beach through gradual dissipation and breaking of wave energy. The offshore reef slope is relatively shallow to enhance surfing opportunities. Conversely, breakwaters, which also can either be submerged or emergent, create a wave shadow zone primarily by direct wave blocking and wave diffraction. As a result they are much smaller in plan area, and provide no surfing enhancement. In fact, offshore breakwaters can result in a net loss of surfing area which should be mitigated if considered part of a sand retention strategy.

Coastal engineers understand much more about the sand retention characteristics of both emergent and submerged breakwaters than reef structures. It is of interest for purposes of this study to provide an assessment of the economic viability of breakwaters as sand retention measures, since much more is known about them. In addition, some cities may wish to consider them as an optional strategy if they appear feasible with mitigable impacts.

Some general assumptions were required as part of this overall economic assessment as follows:

- A continuing large scale sand nourishment program was assumed to occur throughout the project life for all alternatives.

- Each fixed structure that is used in conjunction with beach nourishment should be filled to the upper limit of its holding capacity. Where uncertainties exist, fill should exceed the calculated upper limit of the holding capacity of the structure. The purpose of pre-filling the structure induced salient or fillet is to eliminate any downcoast loss of sand due to deposition at the project site.

- All structures should minimize downcoast shoreline erosion.
- A structure life of 50 years is assumed. This is standard coastal engineering practice for concrete and armor stone structures.

Sections 3.1 through 3.3 describe the development of the offshore breakwater, artificial sand retention reefs, and groin concepts, respectively. Section 3.4 describes the economic analysis of each concept.

3.1 OFFSHORE BREAKWATERS

3.1.1 Relationships Between Structure Characteristics and Retained Beaches

This section summarizes methodologies to forecast the relationship between offshore breakwaters and sand retention. Methods are based on review of the performance of known breakwaters in Southern California, as well as published empirical relationships. Please refer to Appendix 4 for more detailed discussion and analysis.

Offshore breakwaters are established measures for artificial sand retention. They reduce wave heights and alter the wave direction in their lee, allowing sand to build up in their wave shadow zone. Too large of a wave shadow zone can result in buildup of beach sand all the way out to the breakwater, resulting in what is termed a *tombolo*. A sand bulge that does not reach the breakwater but allows for ongoing transport of sand through the breakwater lee is called a *salient*. Creation of a tombolo is typically not desired due to excessive buildup of sand on the upcoast side of the tombolo, and associated sand loss downcoast.

<u>Approach</u>

The key parameters that control the sand buildup behind an offshore breakwater include the following:

- Shore-parallel length of the breakwater
- Distance offshore of the pre-project shoreline
- Wave transmission characteristics of the breakwater, i.e. amount of wave energy that can pass over and/or through the breakwater
- Local wave and tide climate

Existing literature and methods regarding the performance characteristics of offshore breakwaters was augmented by our assessment of the behavior of the beach retained behind three offshore breakwaters in Southern California. These beaches include the salient in the lee of the Santa Monica breakwater, the salient (pre-beachfill) and later tombolo (post-beachfill) in the lee of the Venice Beach breakwater, and the salient in the lee of the ship wreck off Coronado. These beaches are shown in Figures 3-1, 3-2 and 2-4, respectively.

Figure 3-1 Salient in the Lee of the Santa Monica Breakwater in 1940 (USACE-LAD, 1995)

Figure 3-2 Venice Breakwater and Transient Tombolo

Figure 3-3 shows the resulting relationship between breakwater configuration and retained beach area, based on a combination of established relationships augmented with Southern California experience described above. The plot is a culmination of a detailed performance assessment described in Appendix 4. The purpose of the plot was to develop a means to compare different structure lengths, distances from shore, and transmission coefficients, in terms of their efficiencies in retaining a beach and their cost, for the Southern California wave climate. Based on the figure, the most cost effective structure would be that with the highest value of A_s/V_b, where A_s represents the retained beach area and V_b represents the structure volume which is directly related to structure cost.

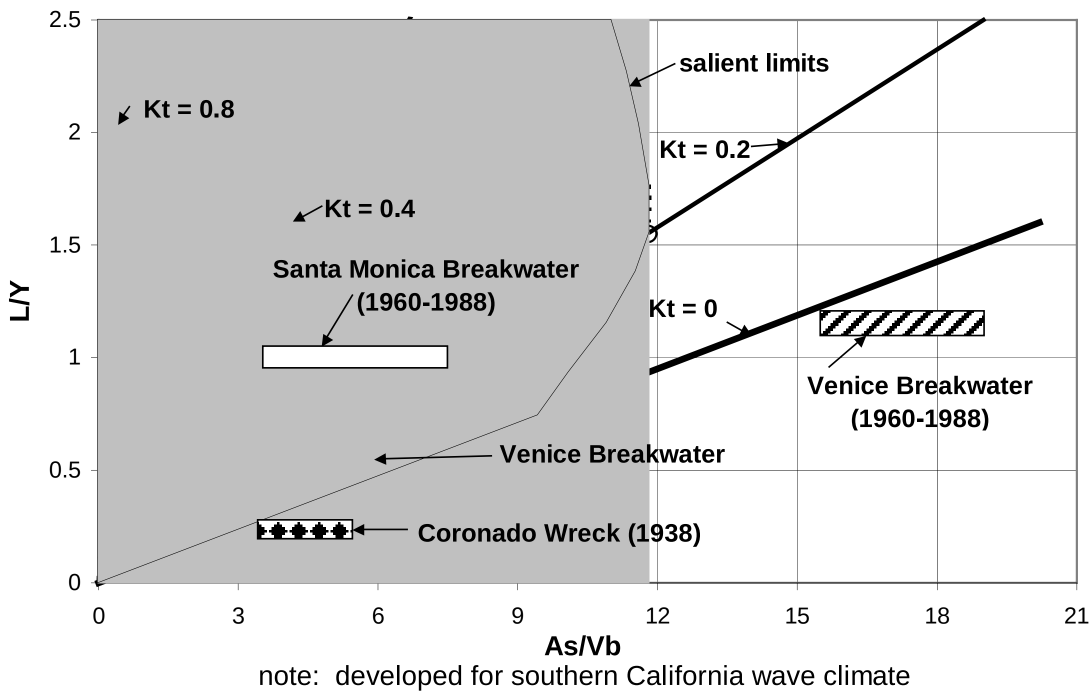

Figure 3-3 Benefit to Cost Chart for a Standardized Breakwater

Inspection of Figure 3-3 leads to some general guidelines:

- Not unexpectedly, a breakwater that provides little wave transmission (either through the structure or due to overtopping of a low structure) will likely produce the best benefit-to-cost structure.
- The most effective sand-retention structure would be an emergent breakwater with a transmission coefficient of 0.2 and a length of structure (L) to distance offshore (y) ratio of 1.5. It should be noted, however, that an offshore breakwater with an L/y ratio of 1.5 does pose the risk of tombolo formation which should be avoided.
- Fully submerged breakwaters structures (transmission coefficient at 0.4 and greater) do not appear to be cost effective, even very long ones close to shore.

As an additional comment, care must be taken when designing a submerged breakwater or reef. Experience has shown that offshore structures that overtop can cause seabed scour in their lee and high currents that can move sediments away from the salient.

Conceptual Design

Using this methodology, a generic offshore breakwater design was developed for the sand retention economic analysis. Specific characteristics of the breakwater include:

- Length of 1,000 feet
- Distance offshore of 1,000 feet to maximize cost/benefit and minimize risk of tombolo formation
- Maximum width (i.e. distance offshore) of salient of 500 feet
- Total length of retained beach (alongshore dimension) of 3,000 feet
- Total retained beach area of 750,000 square feet (about 17 acres)
- Structure crest elevation of +6 feet MLLW (about 3 feet above mean sea level).

Figure 3-4 illustrates the breakwater concept.

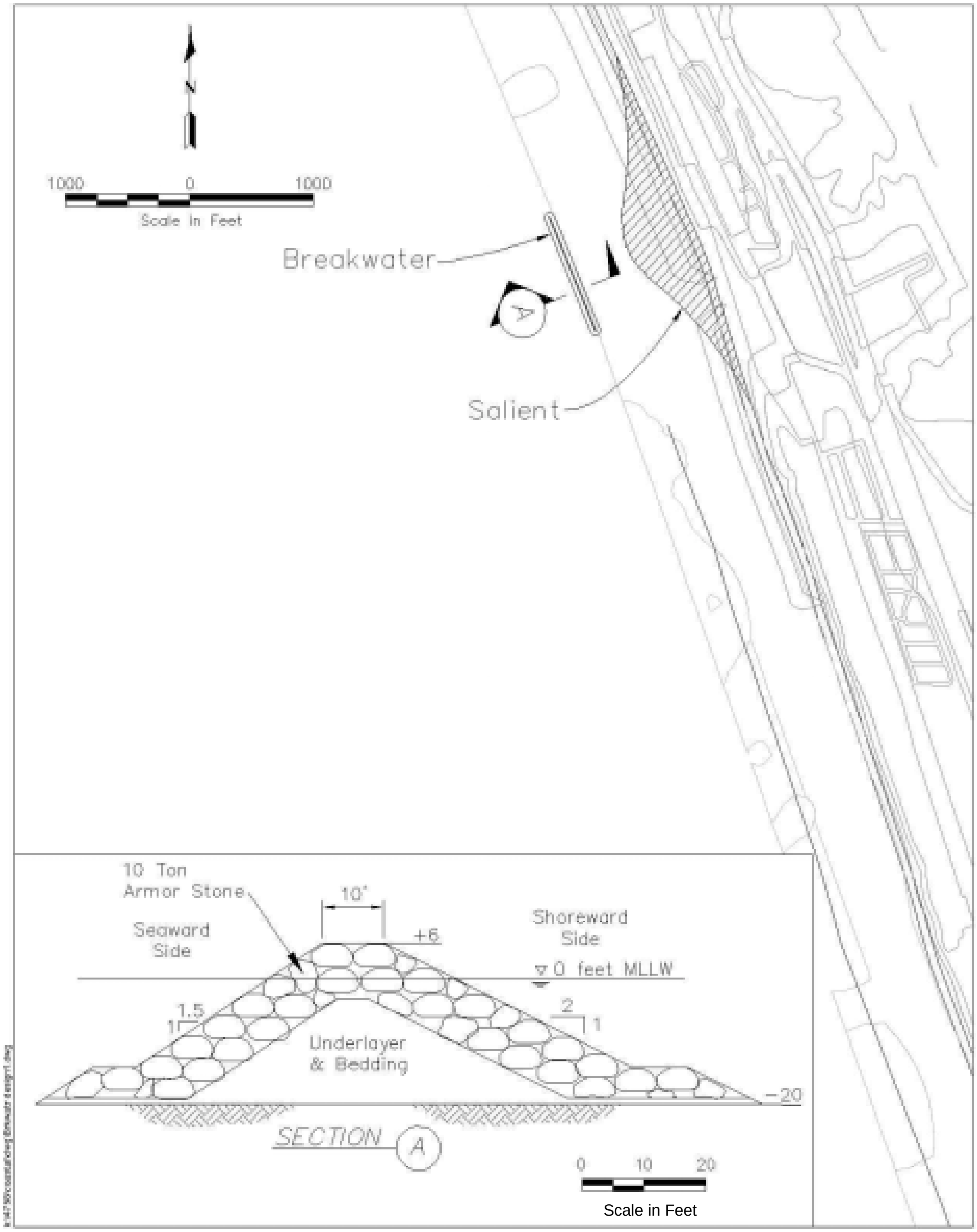

Figure 3-4 Offshore Breakwater Conceptual Design

3.1.2 Impacts and Mitigation

Limited effort was focused in this study regarding impacts and mitigation of offshore breakwaters since this type of retention measure was not specified as a candidate structure for implementation. Key impacts that would need to be considered would include an offset for sand impounded behind the structure and loss of recreational surfing opportunities. As for the initial loss of sand to the littoral system associated with the growth of the salient behind the breakwater, this type of impact is typically mitigated by pre-filling the salient volume with sand imported from outside of the littoral system. Loss of surfing opportunities could be mitigated by construction of a separate artificial surf reef, for the sole purpose of enhanced surfing opportunities.

Other potentially key impacts may include direct burial of reef habitat and the potential for creating bird roost habitat that could reduce water quality.

3.2 ARTIFICIAL SAND RETENTION REEFS

The following section summarizes a methodology to forecast the relationship between artificial reef characteristics and sand retention. Methods are based on review of the performance of known reefs in Southern California and elsewhere, as well as published empirical relationships, which are limited. It is important to reiterate that, at least based on available information, few artificial reefs successfully retain permanent salients. More study is required. Please refer to Appendix 4 for more detailed discussion and analysis.

3.2.1 Relationships Between Structure Characteristics and Retained Beaches

Artificial reefs are three-dimensional features that reduce wave heights in their lee. All reefs in this discussion have a surfing component as this was identified as being a desired quality by each city indicating an interest in an artificial retention reef strategy. As stated previously, the primary difference between breakwaters and reefs is that breakwaters reduce wave energy by direct blocking of wave energy while reefs reduce transmitted wave energy through breaking and dissipation. In addition, breakwaters eliminate surfing areas while reefs can actually enhance surfing opportunities.

To effect wave dissipation, reefs are wide in the cross-shore direction. Large and irregularly shaped reefs refract waves thereby altering their approach direction toward the shoreline. Changes in wave energy along the shore resulting from smaller reefs are due primarily to an attenuation or dissipation of wave energy as it passes over the structure. If the wave conditions in the lee of an artificial reef are sufficiently altered, they produce a change in the longshore component of wave energy resulting in a bulge in the shoreline that is retained in dynamic equilibrium. Two examples of Southern California reefs that retain sand are included in Figures 3-5 and 3-6.

Figure 3-5 San Mateo Creek (Trestles)

Figure 3-6 Topanga Creek

Natural reefs that enhance sand retention and surfing are generally located nearshore with a crest (or plateau) elevation near the water level. These reefs can be either shore-connected or offshore, each with varying shoreline responses. Submerged reefs rarely generate substantial adverse effects on neighboring beaches since they have little impact on the longshore littoral drift. Shore connected reefs allow sand to pass on the beach, seaward, and over the top at times, while offshore reefs allow sand to pass in the lee of the reef. As sediment is carried along the coast, it moves parallel to the undulating shoreline, just as it is transported parallel to the shoreline on adjacent beaches. As is the case with low-crested offshore breakwaters described in the preceding section, overtopping may result in the ponding of water in the lee of the structure. Erosive currents may be the consequence, with negative impacts on the retained salient.

Approach

Quantitative guidance to predict the size of a salient in the lee of an artificial reef is limited. The procedure utilized in this study to predict reef performance is comparable to that for offshore breakwaters in that the first step is to identify the critical parameters that affect reef performance as a sand retention device. These parameters are illustrated in Figure 3-7, and include:

- Reef length (L) or the alongshore dimension of the reef
- Reef distance (Y) from shore
- Reef width (w_r) normal to shore, and
- Reef freeboard or water depth over the reef (d_s-h_c) where d_s is the water depth at the reef toe and h_c is the crest elevation above the seabed.

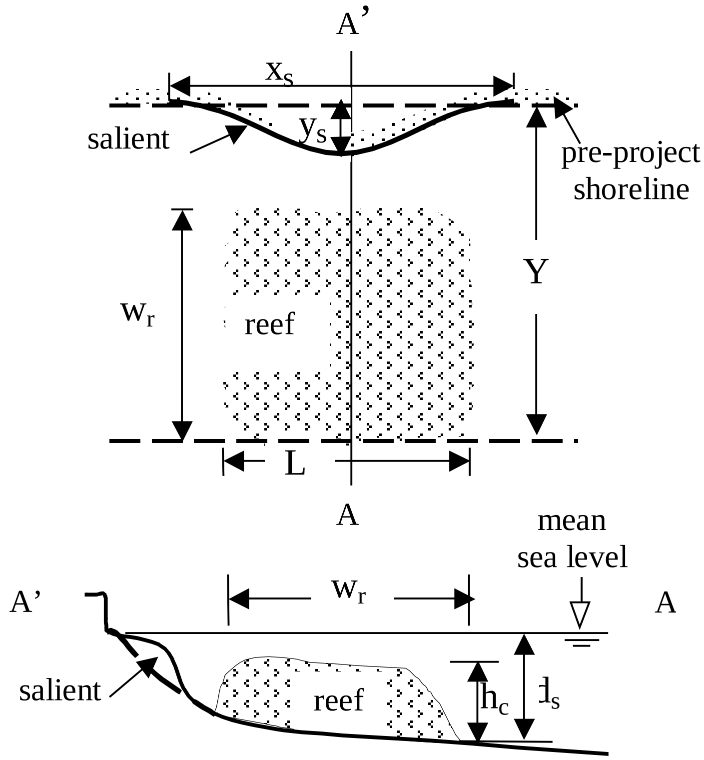

Figure 3-7 Definition Sketch of an Artificial Reef and Salient

Uncertainty in the artificial reef performance is greater than in the offshore breakwater estimates because data describing the bathymetry over local reefs is not available in sufficient detail to provide guidance. Thus only approximate assumptions could be made. Due to the paucity of information regarding Southern California reef performance, greater reliance was placed on experience elsewhere, including laboratory studies and empirical data from coastlines in Japan, New Zealand and Australia. The following summarizes the general approach to assess reef performance:

- Utilize any applicable methods available for design of sand retention reefs
- Augment these data with information from reefs found in Southern California
- Limit the design to those features that are necessary to perform a cost comparison and to further the discussion.

A shore-connected reef is recommended over an offshore or barrier type reef for the following reasons:

- Shore connected reefs reduce wave diffraction around the reef which can reduce salient size.

- Shore connected reefs force any water ponding to occur over the reef reducing the possibility of scouring currents in the lee.

- The volume of a reef constructed close to shore is less because of the shallower water, resulting in lower construction cost.

- Natural examples of shore connected reefs in Southern California exist which can assist in development of design guidance.

With the lack of detailed bathymetry and reef shelf elevations, it was not possible to optimize the reef design using a cost benefit approach as was done for the breakwaters in the preceding section. Figure 3-8 summarizes the relationship developed in this study for the purposes of predicting salient area as a function of reef area.

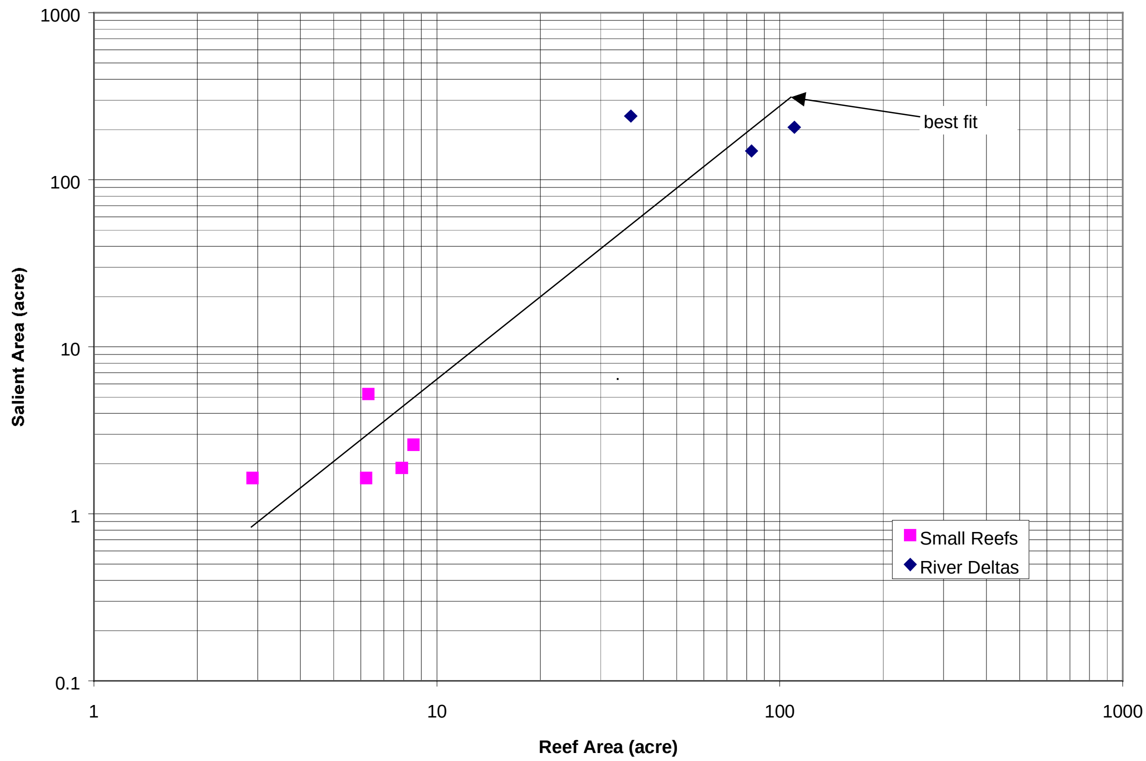

Figure 3-8 Salient Size as a Function of Reef Plan Area

<u>Conceptual Design</u>

A conceptual artificial sand retention reef design was developed based on methods described above. Specific reef and associated performance characteristics are summarized as follows.

- Total reef plan area of 5 acres
- Retained beach salient area of 2 acres
- Reef alongshore length (L) of 900 feet
- Reef width (w_r) of 320 feet
- Offshore slope of 1:20 (vertical:horizontal) to enhance the surf break
- Shelf elevation ranges from –2 feet MLLW to +1 feet MLLW
- A schematic of the reef concept is shown in Figure 3-9.

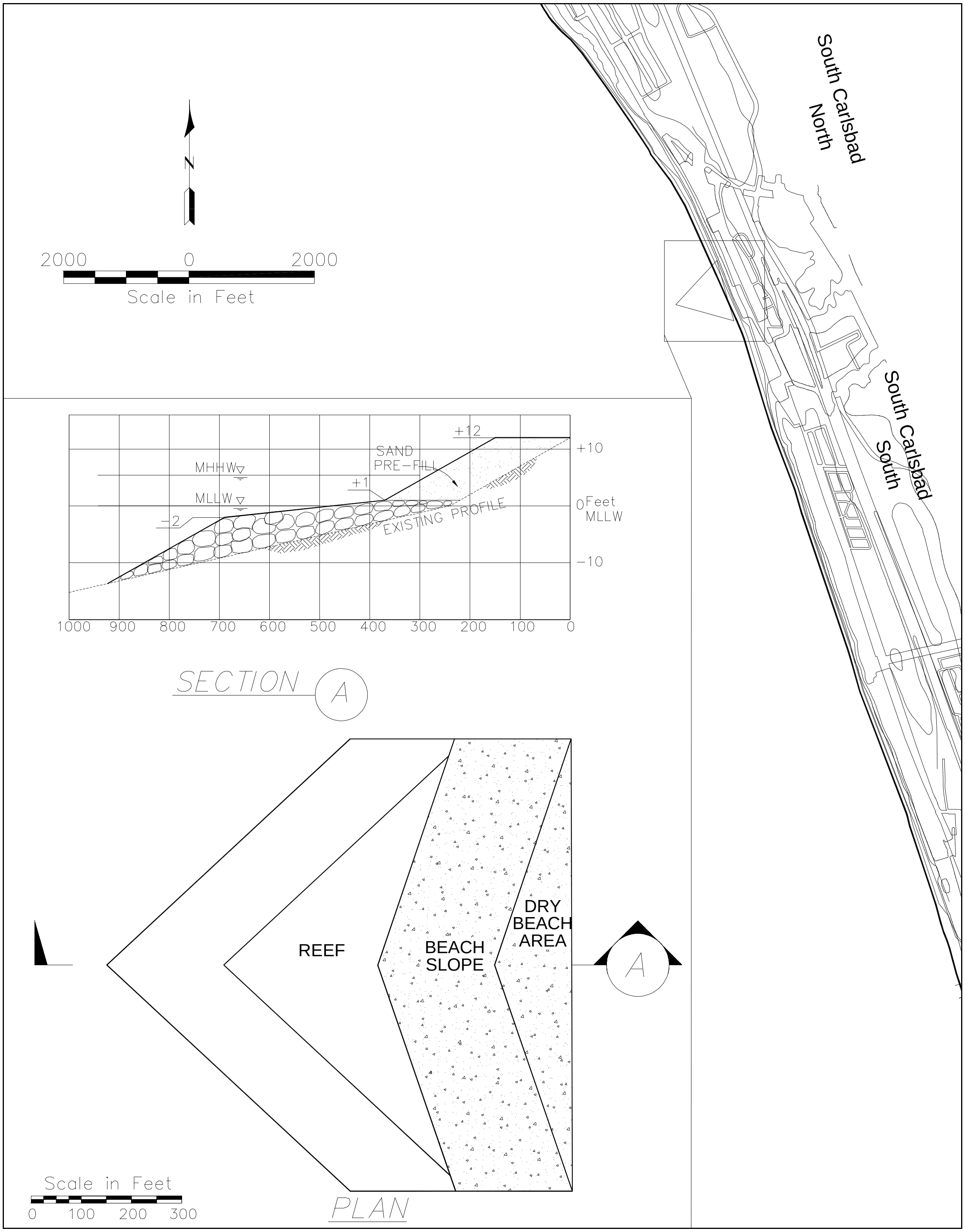

Figure 3-9 Sand Retention Reef Conceptual Design

3.2.2 Impacts and Mitigation

As described for the breakwater concept, impact of net sand loss to adjacent beaches associated with impounding of sand in the lee of the retention structure can be offset by pre-filling the estimate volume of the retained beach with sand from outside the littoral cell.

Although the beach would be widened as a result of construction of a shore-connected reef, there would be a net loss of swimming beach length. It has not been determined whether this impact is significant and requiring mitigation.

The focus of this screening analysis is on the implementation of artificial sand retention reefs. As stated previously in this report, sensitive biological habitat exists within North County San Diego. A biological reconnaissance was done for the San Diego Regional Beach Sand Project that was used as the basis for assessment of potential impacts from this sand retention strategy. Impacts are determined assuming a submerged or emergent reef is the option at each site. Recommended sites are shown with arrows on the map attached with this report.

Table 3-1 summarizes information for the reef alternative. The first column in the table includes existing sensitive resources at each candidate site. The second column addresses the beneficial impact of creation of sub-tidal hard substrate habitat. The next three columns relate to direct burial and/or indirect sedimentation to reef habitat. For the direct impacts, discrimination was made between reef habitat with sensitive resources (e.g., surfgrass) and ephemeral reef habitat without sensitive resources. Impacts to sensitive reef areas have the potential to be significant. Impacts to ephemeral reef habitats most likely would be adverse, but not significant. In fact, placement of higher relief reef habitat in an area of ephemeral reef may have habitat enhancement benefits. For the indirect impacts, only sedimentation to sensitive reef areas was considered. Indirect sedimentation impacts to sensitive reef areas have the potential to be significant. Sedimentation to ephemeral reefs is a natural seasonal phenomenon and would not constitute a significant impact. The last column of the tables relates to proximity to nesting sites of endangered least tern. Since turbidity will be generated during construction of either the reef or breakwater alternatives, sites within about 2 miles of nesting sites will be of potential concern to resource agencies, and construction schedules most likely would require agency review.

The Oceanside and Torrey Pines sites have no identified constraints at this time. Sites with no constraints other than potential construction-related turbidity impacts to least terns include Coronado and Imperial Beach. Two sites have a low potential for impacts to sensitive reef habitat including Moonlight Beach and Solana Beach. Two sites have a higher potential for impacts to sensitive reef habitat including North Carlsbad (hence selection of South Carlsbad) and Solana Beach. Placement of a reef at Torrey Pines has the potential for increased sedimentation at the mouth of Los Penasquitos Lagoon if placed too far north. The potential for significant impacts to sensitive resources at sites considered to have a low potential or potential for impact requires further evaluation.

Another key impact to consider for submerged structures is public safety. Construction of an artificial structure in the surf zone could pose a public safety hazard to swimmers, surfers and boaters. Assessment of public safety impacts was beyond the scope of this study. Potential mitigation measures could include public education, increased lifeguard patrol services, clear and effective signage, and the like. Buoys delineating the reef extent may also be considered, although such structures in the surf zone may pose their own safety risk, including the potential for surfboard leashes to become entangled in the buoy mooring.

Table 3-1 Summary of Potential Impacts from a Sand Retention Reef

Location	Known/ Potential Sensitive Resources	Creation of Hard Substrate	Burial of Sensitive Reef Habitat Inshore of Created Reef	Burial of Ephemeral Reef Habitat	Sedimentation of Sensitive Reef Habitat	Construction Turbidity < 2 Miles from Least Tern Nesting Site
1. Oceanside	No	Yes	No	No	No	No
2. South Oceanside (option)	Scattered rock with patchy surfgrass to south	Yes	low potential	low potential	low potential	No
3. North Carlsbad	Scattered low to high relief reef with surfgrass	Yes	Potential	potential	potential	No
4. South Carlsbad (North)	Low to high relief reef with surfgrass	Yes	No	No	low potential	No
5. Moonlight	Limited scattered reef, very sparse surfgrass	Yes	low potential	potential	low potential	No
6. Solana Beach	Scattered reef with patchy surfgrass	Yes	Potential	potential	potential	Yes
7. Solana Beach (option)	Sand to patch reef without sensitive resources	Yes	low potential	Potential	low potential	Yes
8. Torrey Pines	No	Yes	No	No	No	No
9. Mission Beach	No	Yes	No	No	No	No
10. North Coronado	No	Yes	No	No	No	Yes
11. Imperial Beach	No	Yes	No	No	No	Yes
12. Imperial Beach (south)	Kelp offshore	Yes	none known inshore	?	No	Yes

Mitigation for Biological Impacts

No significant impacts are expected at most sites and mitigation therefore may not be required. There is some low potential for impacts at South Carlsbad, Moonlight and Solana Beach. Additional evaluation may be needed to determine the significance of potential impacts and required mitigation at those sites.

3.3 GROIN FIELD

Groins are long, narrow structures placed approximately perpendicular to the shoreline to build or widen a beach by trapping littoral drift. The widened beach can then serve recreational and shore protection functions. The desired sand retention strategy as conceived with the City of Oceanside consists of three major components: (1) construct groins long enough to provide sufficient sand retention (2) pre-fill the groin fillets; and (3) modify the Federal sand bypassing at Oceanside Harbor to extend to south of the groin field thereby minimizing erosion impacts on downcoast beaches.

3.3.1 Relationships Between Structure Characteristics and Retained Beaches

This section summarizes the method used to predict the relationship between a system of shore perpendicular groins, known as a groin field, and the retained sandy beach. Groins are fundamentally different from breakwaters and artificial reefs in that they do not attempt to modify transmitted wave energy as a mechanism for reducing longshore sediment transport, but instead they directly block the currents that carry the suspended sediment along the coast.

Groins and groin fields have been used successfully to retain sand throughout the world and are recognized coastal engineering structures. Conversely, if not applied properly, groins have also been the primary cause of numerous cases of beach erosion. The accumulation of material (accretion) on the updrift side is accompanied by a corresponding amount of erosion on the downdrift side of the groin. Knowing this, two essential site considerations are: (1) in order for sand to be trapped, there must be an adequate supply and (2) there is always a potential for downdrift erosion problems.

Approach and Assumptions

Several general rules and guidelines are available to assist in this conceptual level design of a groin field. The approach and assumptions are listed here:

- Review previous studies and designs of similar work in the same project area (USACE, 2000; Moffatt & Nichol Engineers, 1999; Noble, 1983a; and Noble, 1983b).
- Estimate the blocking distance for the project site based on nearby structures (Table 2-3).
- Estimate the fillet angle at the project site based on nearby structures (Table 2-3).
- Choose a desired beach area. In this case the beach area equals that of the Offshore Breakwater Concept.

- Assume the net sediment transport direction at Bucaneer Beach is to the south. As stated in Appendix 2, the present understanding of the longshore sediment transport is weak in the Oceanside Littoral Cell. It is known that the net to gross transport ratio is small, and the general consensus is of net transport to the south.

- Calculate beach length, maximum width, and groin spacing based on fillet angle.

- Use the Shore Protection Manual for cross-section design (USACE, 1984).

- Assume the groins are nearly 100% impermeable to hold pre-filled sand in place.

Conceptual Design

Using this methodology, a groin field design was developed for the sand retention economic analysis. Specific characteristics of the groin field are:

- Individual groin lengths of 930 feet

- Two groins spaced 1,500 feet apart

- Maximum fillet width of 280 feet

- Minimum beach width of 150 feet between groins

- Total retained beach area of 750,000 square feet (about 17 acres)

- Structure crest elevation of +14 feet MLLW at the beach berm, sloping down to +3 feet MLLW in the water

- The construction material has not been determined. Sand-filled geotextile bags or removable sheet-piles could be used for a temporary pilot structure, and armor stone would normally be used for a more permanent structure. Armor stone is assumed for the cost analysis.

Figure 3-10 illustrates the groin field concept.

Another alternative worth consideration is locating a single groin under the Oceanside Pier. This location could reduce sand bypassing costs to the City as it would not extend the distance of the Federal sand bypassing project beyond where it is normally discharged. This alternative would minimize aesthetic impacts and impacts to recreational waters as the structure would be located immediately adjacent to the existing pier.

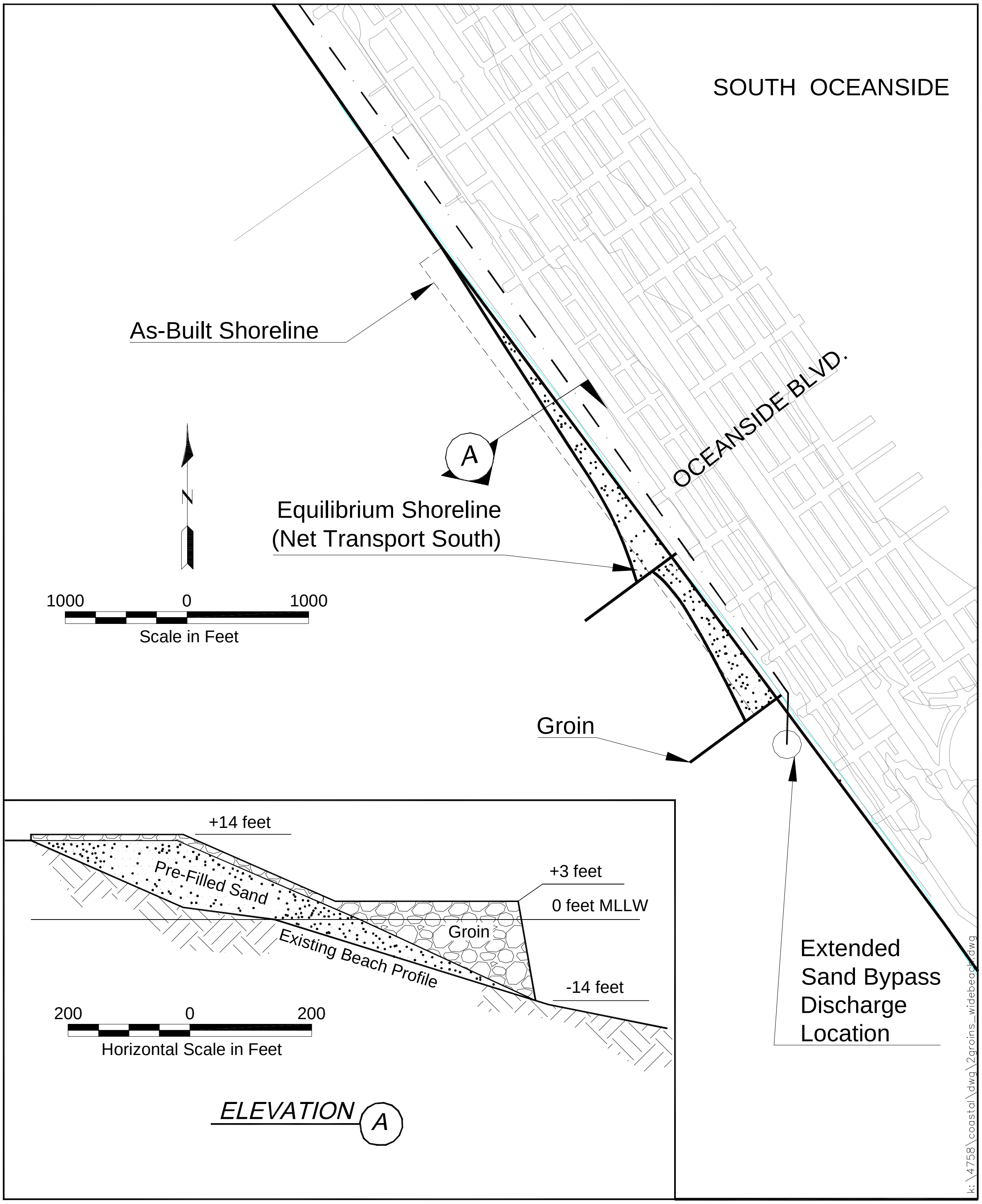

Figure 3-10 Groin Field Conceptual Design

3.3.2 Impacts and Mitigation

Initial areas of concern for this alternative are impacts to bottom habitat due to sand placement, impacts to recreational surfing areas, and potential downcoast erosion. The site selection process included avoiding areas of reef habitat. There are notes of some scattered rock at the -30 foot contour that could be covered with sand due to beach widening. As possible mitigation, a large amount of hard substrate subtidal habitat will be created with the addition of rocky groins. Experience at nearby groins indicates a possible improvement to recreational surfing, but this aspect has not been studied for this project. No surfing mitigation is proposed for this alternative. Downcoast erosion would be addressed by pre-filling the groin field, extending the Federal sand bypassing at Oceanside Harbor to south of the groins, regular beach monitoring, and possible re-nourishment. As an added benefit, the groins are expected to minimize the amount of sand migrating back north into Oceanside Harbor, thereby making this material available for beaches to the south.

In addition, there is a potential for creating bird roost habitat that could reduce water quality.

3.4 ECONOMIC ANALYSIS OF SAND RETENTION STRATEGIES

The preceding sections describe development of offshore breakwaters, artificial reefs, and a groin field as sand retention measures, resulting in relationships between structure characteristics and the amount of equilibrium beach area retained by the structure. The next step was to estimate life cycle costs of each concept for comparison with the life cycle cost of maintaining the same beach area through periodic nourishment alone.

An economic analysis of various alternatives, e.g. structure vs. nourishment alone, requires a comparable cost basis. Costs presented in this report represent *present value costs*, i.e. the amount of capital required today to both build a structure and maintain it periodically in the future, taking into account inflation, current interest rates, and construction cost escalation (not necessarily the same as the overall inflation rate). The project life for the economic analysis was assumed to be 50 years.

3.4.1 Present Value Cost of Retention Strategies

Table 3-2 summarizes the present value cost analysis for construction of (1) a 1,000 foot long offshore breakwater predicted to retain a 750,000 square foot beach (approximately 17 acres); (2) an artificial sand retention reef estimated to maintain a 87,000 square foot beach (approximately 2 acres); and (3) a groin field predicted to retain a 750,000 square foot beach. Itemized cost elements included:

- Initial construction cost for the structures
- Pre-filling the estimated retained beach volume with sand from outside the littoral zone as mitigation for impacts associated with sand impoundment behind the structure

- Full mobilization costs were assumed for the beach pre-fill since it was not reasonable to assume that the construction would be concurrent with a regional beachfill project

- Future maintenance of the structures

- Allowance for future replenishment of the retained beach area due to storms

- Allowance for engineering, design, supervision and administration costs

- Allowance for surfing impact mitigation cost (breakwater only), assumed to be construction of an artificial surf reef (without sand retention characteristics) in the vicinity.

More detailed cost summaries are tabulated in Appendix 1.

Table 3-2 Present Value Costs for Sand Retention Strategies to Maintain Specified Beach Areas for 50 Years

Sand Retention Strategy	Present Value Cost ($)	Cost per Square Foot of Retained Beach ($/sf)
Offshore Breakwater (17 Acres of Retained Beach)		
w/o Allowance for Post-Storm Fill	$25,600,000	$30
w/ Allowance for Post-Storm Fill	$33,400,000	$40
Artificial Sand Retention Reef (2 Acres of Retained Beach)		
w/o Allowance for Post-Storm Fill	$8,900,000	$100
w/ Allowance for Post-Storm Fill	$9,300,000	$110
Groin Field (17 Acres of Retained Beach)		
w/o Allowance for Post-Storm Fill	$16,200,000	$20
w/ Allowance for Post-Storm Fill	$20,400,000	$30

For more direct comparison purposes, a reduced breakwater concept was developed that would retain the same two-acre beach area as that predicted for the sand retention reef. The cost per square foot of retained beach increased to $70 and $80 for the without and with post-storm filling requirements, respectively. The primary reason for the significant increase in cost was the increased relative cost of the surfing mitigation. Similar values for a groin field retaining a two-acre beach are increased to $120 and $130 for without and with post-storm sand filling. The relative increase is mainly due to the groin costs dropping by only 14 percent while the beach area decreases by 88 percent.

3.4.2 Present Value Cost for Beach Nourishment Alone

The premise of this economic analysis was to compare total present value costs of the structure-retained beach areas to maintenance of the same beach area through nourishment alone. Present value cost estimates were developed to estimate the present value cost of maintaining the same dry beach area as that estimated to be retained by the breakwater or reef, but through beach nourishment alone. As was done for the present value costs of the retention strategies, the present value costs for beach nourishment alone assume that the desired dry beach area will be maintained over a 50 year period through periodic beachfills.

It is important to point out that the stability of these periodic beach fills is difficult to predict due in part to the following:

- limited data exists on beachfill longevity
- fill stability will be greatly affected by the future wave climate which can be highly variable
- the future frequency and volume of future regional beach fills in unclear.

Predictions were made of beachfill longevity based on available historic records and studies of beachfill erosion rates, including supporting studies for the Regional Beach Sand Project currently under construction. It was predicted that Oceanside, Encinitas and Solana Beach would require the most frequent re-nourishment, followed by Coronado and Imperial Beach, with Torrey Pines and South Carlsbad requiring the least frequent re-nourishment.

Table 3-3 summarizes estimates of the present value cost to maintain the same dry beach area as that predicted for the retention strategies. More detailed cost information is included in Appendix 1.

Table 3-3 Present Value Costs to Maintain Specified Dry Beach Area for 50 Years

Beach Nourishment Size and Location	Present Value Cost ($)	Cost per Square Foot of Beach ($/sf)
Oceanside / Encinitas / Solana Beach		
17 Acre Beach	$57,000,000	$80
2 Acre Beach	$20,300,000	$230
South Carlsbad / Torrey Pines		
17 Acre Beach	$22,400,000	$30
2 Acre Beach	$5,900,000	$70
Coronado / Imperial Beach		
17 Acre Beach	$26,500,000	$40
2 Acre Beach	$7,700,000	$90

3.4.3 Summary of Economic Analysis

Table 3-4 provides a comparison of the present value cost for structure-retained beach area and beaches maintained by periodic nourishment alone.

Table 3-4 Comparison of Present Value Cost of Structure-Retained Beach Area and Beach Area Maintained By Nourishment Only

Beach Nourishment Size and Location	Structure-Retained Beach ($/sf)	Beach Maintained by Nourishment Only ($/sf)
Oceanside / Encinitas / Solana Beach		
17 Acre Beach (Breakwater)	$40	$80
2 Acre Beach (Reef)	$110	$230
17 Acre Beach (Groin Field)	$30	$80
South Carlsbad / Torrey Pines		
17 Acre Beach (Breakwater)	$40	$30
2 Acre Beach (Reef)	$110	$70
Coronado / Imperial Beach		
17 Acre Beach (Breakwater)	$40	$40
2 Acre Beach (Reef)	$110	$90

Review of the above results indicates that for Oceanside, employing any of the three structure alternatives appears preferable over sand nourishment alone when considering only costs. For the other more erosive beach areas such as Encinitas and Solana Beach, implementation of either an offshore breakwater or artificial sand retention reef appears to be feasible based on cost alone. Although no city requested consideration of an offshore breakwater as their retention measure of choice, the results demonstrate their cost effectiveness relative to artificial reefs. This makes sense given breakwaters utilize less volume of material and penetrate the water surface resulting in less wave transmission. Groin fields were not analyzed for locations other than Oceanside due to a lack of interest. Even with the less effective retention reef measure, economic benefits are demonstrated based on costs.

In less erosive beach areas, the analysis indicates that life cycle costs would be comparable between sand retention structures and nourishment alone, with sand retention structures being slightly higher. Given this situation, the option of nourishment alone may be preferable, since current sentiment is generally against implementation of hard, artificial structures.

In summary, the economic analysis indicates that, based solely on a life cycle cost analysis, a sand retention strategy incorporating artificial sand retention structures appears warranted along the more erosive beaches in San Diego county. Conversely, such structures do not appear to be economically justified in more stable beach locations. Again, this conclusion is based on costs, and does not quantitatively consider relative benefits between alternative strategies. Although the benefits of a wider beach are inherently included since the analysis is based on retaining the same amount of beach area, benefits not included are habitat enhancement (and detriment) and surfing enhancement (vs. loss of swimming beach).

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Artificial sand retention measures were found to have the potential to be cost effective in locations demonstrating the greatest problems in beach erosion, with no clear choice in the lesser erosive sites. This finding must be qualified in that significant assumptions were required to be made that were integral to the economic assessment. Further site-specific and structure-specific study is required before final decisions can be made.

This study evaluated only those structures the communities asked for. Others might be as effective or even more effective in retaining a beach. While the structures discussed certainly deserve close scrutiny, decision-makers should fully appreciate the boundary between practical capability and wishful thinking. An especially important consideration is structure size. The size of the retained beach will almost always be proportional to the size and/or the number of structures, and hence their cost. Small structures will usually retain small beaches; structures that are too small will retain no beach.

The Regional Beach Sand Retention Strategy developed in this study evaluated the possibility of (1) enhancing natural retention structures like headlands and river deltas, (2) enhancing existing artificial structures that possess a beach retention function, such as jetties and groins, and (3) creating new artificial beach retention structures. The great benefit of detailed, phased, site-specific investigations comes because large, location-dependent differences in the incoming sand supply, local shoreline orientation and irregularities, local bathymetry, and deep water wave climate, all interact to produce substantial variations in the ratio of retained beach size to structure dimensions for each of the three structure types considered. Choosing the right structure for the environment and optimizing its location, configuration and dimensions, is where real gains in efficiency can be made. The goal is practical in the sense it focuses on the most favorable options to retain a beach, including no structures.

Decisions that affect beaches usually consider factors other than beach and structure size. Among them are the probability of success, environmental consequences such as downcoast impacts, impacts on surfing and living resources, upfront and down-the-road costs, aesthetics, construction disruptions, legal considerations, and political factors including the desires of people who want no coastal projects. Some of the beaches likely to be retained by artificial structures will be "specialty" beaches that may superbly meet some needs, but not all of the wide range of beach recreational and protection functions that exist.

This effort is just the first step in the long journey that ends with an enhanced beach retained by a structure. Recommendations provided in this report are based on reconnaissance-level evaluations. A great deal more work is needed to prove or disprove them as the "best" structures for the sites selected by the local government officials. More detailed functional investigations are definitely warranted to fine tune the structures to the desired beaches. In all cases, the evaluations conducted in this analysis raised questions that require further functional investigation before any design is begun on the suggested structures.

During the entirety of this process, permitting questions and funding will require close attention. Given the opposition to structures by some people, it is likely there will also be a certain education element required during the permitting process. Construction follows when all design, regulatory and funding questions have been resolved. Last, and ongoing is monitoring and beach replenishment as needed. Due to cost savings, opportunistic sand sources with an appropriate nearby stockpile will be especially useful adjuncts to the continuing upkeep of structure-retained beaches in San Diego County.

4.2 RECOMMENDATIONS

This study provides a first step in establishing both a local and region-wide sand retention strategy. The results are promising, but a great deal more work must be done before decisions for implementation can be made with sufficient confidence in the results.

Artificial sand retention reefs were generally identified as the measure of choice. Given the limited knowledge and performance data for this type of structure in Southern California, efforts should be focused on expanding this knowledge base. Specific recommendations include:

- Closely track performance of the Narrowneck Reef developments in Australia.
- Augment findings of this study with the recently initiated study of sand retention reefs sponsored by the California Coastal Conservancy.
- Update findings of this study with monitoring data from the Regional Beach Sand Project now underway.
- Initiate a detailed measurement program of the physical features of existing natural sand retention reefs followed by physical model studies of any proposed artificial sand retention reef.
- Construct a prototype sand retention reef in Southern California before full implementation. This structure could be built from large sand filled geotextile bags to minimize construction costs and to allow for relatively easy removal. It is suggested that this reef be built in two stages, with the second stage being a fine tuning and possibly expansion of the primary design. This would yield invaluable engineering data to better optimize future designs. A detailed shoreline monitoring program would be an essential element of this prototype-scale pilot study to assess both performance and impacts.

- A prototype-scale pilot study of groin performance could also be considered in Oceanside. As for the retention reef concept, the temporary groin should be removable, and possibly adjustable. Detailed monitoring would be a critical element of project implementation, particularly due to the concerns regarding downcoast impacts.

5.0 GLOSSARY OF TERMS

The following provides definitions of key terms. Definitions are presented in the context that they are referred to in the report.

BLOCKING DISTANCE – Minimum length of a sand blocking structure (e.g. groin) before it will have any impact on retaining a permanent beach.

BREAKWATER – A structure protecting a shore area from waves for purposes of sand retention.

DELTA – An alluvial deposit formed at a river mouth.

DOWNCOAST – In the U.S., the coastal direction generally trending toward the south.

DOWNDRIFT – The direction of predominant movement of littoral materials.

DIFFRACTION – When part of a train of waves is interrupted by a barrier, such as a breakwater, the effect of diffraction is manifested by propagation of waves into the sheltered region within the barrier's geometric shadow.

EMERGENT – Above normal water levels at all times.

FILLET – (pronounced *fil'-let*) Wedge-shaped area of sand accretion on the updrift side of a groin.

FILLET ANGLE – Angle between the groin-adjusted shoreline and the original shoreline.

GROIN – A sand retention structure built perpendicular to the shoreline to trap littoral drift or retard erosion of the updrift shore.

JETTY – A structure extending into a body of water, designed to prevent shoaling of a channel by littoral materials.

LEE – Shelter, or the part or side sheltered from the wind or waves.

LITTORAL CELL – A segment of the coast defined for understanding and quantifying movements of sediments that affect the behavior of the shoreline. Cell boundaries are usually established where alongshore movements of sediments into or out of them are known.

REFRACTION – The process by which the direction of a wave moving in shallow water at an angle to the bottom depth contours is changed: the part of the wave advancing in shallow water moves more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alignment with the bottom contours.

SALIENT – A buildup of sand behind a sand retention structure such as an offshore breakwater.

SUBMERGED – Top of the structure is below water during the normal tide range.

TOMBOLO – A bar or spit that connects an offshore sand retention structure to the shoreline.

TRANSMISSION COEFFICIENT – Represents the total fraction of wave energy transmitted both through and over an offshore sand retention structure.

UPCOAST – In the U.S., the coastal direction generally trending toward the north.

UPDRIFT – The direction opposite that of the predominant movement of littoral materials.

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